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BIOACCUMULATION OF HEAVY METALS IN TILAPIA FISH (*OREOCHROMIS NILOTICUS*) FROM WATER AND SEDIMENT OF KYET MAUK TAUNG DAM, MANDALAY REGION

Cho Cho Thin[1], Nan Sandar Myint[2], May Thu Aung[3], May Thu Rein Oo[4] Khin Thu Zar Win[5],
July Maung Maung[6], Kay Lwin Tun[7]

Abstract

Bioaccumulation of heavy metals in fish causes serious threats to human when they are consumed. Thus, detection of toxic metals concentration levels in aquatic component is important. In this study, bioaccumulation of five metals (Fe, Zn, Cd, Pb, As) in meat, gills and liver of Nine Tilapia fish species (*Oreochromis niloticus*), and their environs (water and sediments) of Kyet Mauk Taung Dam, Mandalay Region were analyzed by Flame Atomic Absorption Spectrometer (FAAS) (Perkin Elmer AAanalyst 800 and Winlab-32 software) in Universities' Research Centre (URC). The study was conducted from July 2019 to May 2020. The levels of heavy metal concentration varied as it depended on various tissues of studied fish species. The highest concentrations of Fe and Cd were found in the liver and those of Zn, As and Pb in the gill. The lowest concentrations of all metals were found in meat. According to the results of Transfer Factors, all tested metals accumulated in different tissues of studied fish species came from water and sediment except Fe which came only from sediment. The values observed for all tested metals concentrations in different tissues of studied fish species and their environs except water were lower than the maximum permissible limits. The concentrations of the heavy metals in different tissues from studied fish species did not exceed the dangerous limits given by WHO/FAO and there was no risk for public by eating this species.

Keyword Meat, Gill, Liver, Water, Sediment, Metal Concentration

Introduction

Dams and reservoirs are mainly constructed for irrigation, power generation, flood control, and water supply. They can serve as a sink for accumulation of heavy metals. Their mobility and availability in aquatic environments are primarily controlled by water quality parameters including pH, dissolved oxygen and organic matter content (Ashby, 2011). Dams and reservoirs also play an important role in facilitating the transportation of heavy metals. When water is released from a dam, resuspension of deposited sediments under high flow rate tends to carry heavy metals downstream (Rodbell, 2014).

Anthropogenic activities continuously uninterruptedly increase the quantity of heavy metals in the environment, especially in aquatic ecosystem. Pollution of heavy metals in the aquatic ecosystem is increasing at an alarming rate and has become an important worldwide problem (Malik *et al.*, 2010). Increase in population, urbanization and agriculture activities have further aggravated the situation (Giguere *et al.*, 2004). Heavy metals cannot be reduced and they are deposited, assimilated or incorporated in water, sediment and aquatic animals (Linnik and Zubenko, 2000) and thus, causing heavy metals contamination in water bodies (Malik *et al.*,2010). Therefore, heavy metals can be bioaccumulated and biomagnified via the food chain and finally assimilated by human consumption resulting in health risks (Agah *et al.*, 2009).

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[1] Department Of Zoology (Fisheries And Aquaculture), University Of Yangon
[2] Department Of Zoology, University Of Yangon
[3] University Research Center, University Of Yangon
[4] Department Of Zoology (Fisheries And Aquaculture), University Of Yangon
[5] Department Of Zoology (Fisheries And Aquaculture), University Of Yangon
[6] Department Of Zoology (Fisheries And Aquaculture), University Of Yangon
[7] Department Of Zoology (Fisheries And Aquaculture), University Of Yangon

Heavy metals enter the aquatic environment from both natural pathways and a variety of anthropogenic sources (Youn-Joo, 2003), and they can have a negative impact on aquatic ecosystems, the food chain, and human health. The concentration of heavy metals in biological compartments, such as fish muscle, is a complex combination of biological and ecological variables (Barletta, *et al*., 2012). In fish, these elements can cause disturbances in growth and reproduction, as well as histopathological alterations in the skin, gills, liver, spleen, and kidneys (Vitek, *et al*., 2007). In humans, heavy metals accumulation has hazardous effects on the brain, liver, kidneys, lungs, and muscles (Petera and Viraraghavanb, 2005).

The wide ranges of contaminants are continuously introduced into the aquatic environments and fish from polluted waters seriously threaten human health due to the bioaccumulation of toxic substances in muscle and other tissues (Sekhar, *et al*., 2003). Furthermore, these contaminants also accumulate in different organs of fish and can cause lethal and a variety of sub lethal effects. Among these toxic substances, heavy metals include one of the main dangerous groups, because they are toxic, persistent and difficult biodegradable. The pollution and the contamination of many ecosystems with heavy metals result from both anthropogenic and geologic sources (Ozmen, *et al*., 2006).

In current century, it is stated that many priorities heavy metals had made their way into the aquatic ecosystem and that their concentrations constantly increased (Topcuoglu, *et al*., 2002; Barlas, *et al*., 2006). Various fish species have been found to be good indicators of the heavy metal contamination levels in aquatic systems because they occupy different trophic levels (Burger, *et al*., 2002; Svobodova, *et al.*, 2004; Karadede-Akin and Unlu, 2007). The contamination of heavy metals in organs of fish showed that the aquatic environment is polluted (Farkas, *et al.*, 2000).

Therefore, the present study was to determine the concentrations and bioaccumulation of heavy metals (Fe, Zn, As, Pb and Cd) on different tissues of tilapia fish species that are commercially important and this fish species have been consumed as food by local people. Those of water and sediments from Kyet Mauk Taung Dam were also investigated.

Materials and Methods

Study Area

Kyet Mauk Taung Dam, Mandalay Region situated at 20° 48′ 28.3" N to 20° 50′ N and 95° 15′ 04.4" E to 95° 17′ E was chosen as the study area to analyze element concentrations in tilapia fish species and their environs (water and sediment). The dam is used for irrigation, drinking water and fisheries. The quality of this ecosystem has been degrading due to agriculture and human activities. Therefore, the dam was selected as a study area to investigate the heavy metal concentrations.

Study Period

The study was conducted from July 2019 to May 2020.

Collection of Samples

From the study area, 25 specimens of Tilapia fish species were collected once every two months from local fishermen. Identification of studied fish was carried out followed after Talwar and Jhingran (1991). Collected specimens were washed by tap water until the contamination on the body surface was runoff. Total length (cm) and body weights (g) of specimens were measured. After that, they were dissected using stainless steel scalpels and forceps. A part of each tissue (muscles, gill and liver) was removed and weighed. Samples were put into an oven to dry at 90°C and until reached constant weights. After that they were stored at low temperature until digestion. Digestion of the samples was carried out according to dry method by using a furnace (Model-L-3383). Water and sediment samples were also collected once every two months at study site during the study period.

Sample preparation

Preparation of water and sediment

Each water sample was filtered through a 0.45 μm Whatman filter. The sample was analyzed directly.

The sediment sample was sun dried, grounded and sieved with 200 mm sieve to obtain a find powder. 1.0 g of dried sediment sample in a crucible was placed in a furnace at 200°-250° C for 30 min, and then made ash for 4 hours at 480° C. Then the sample was removed from the furnace and cool down, 2mL of nitric acid was added and evaporated to dryness on sand bath. Then, 2 mL of concentrated HCl was added and transferred to furnace in which the temperature was raised slowly to 450° C and hold at this temperature for 1 hour. The crucible was then removed, cooled and 50mL of deionized water was added. The solution was filtered through 0.45μm Millipore filter paper and then transferred to 25 mL volumetric flask by adding distilled water (Issac and Kerber, 1971). The digested sediment sample was analyzed for heavy metals using the Flame Atomic Absorption Spectrometer (FAAS) (Perkin Elmer AAanalyst 800 and Winlab-32 software) at Universities' Research Centre (URC).

Preparation of fish

Meat, gill and liver samples were dried to constant weight in an oven and dried samples were weight and stored in airtight containers. Digestion was conducted according to dry method. Five grams of dry sample was placed into crucible. And then transfer to a furnace (Model-L3383) and slowly raise temperature to 500° C for 2 hours. Samples were allowed to ash overnight. Once removed, samples were allowed to cool in room temperature and 5 mL nitric acid were added and swirl. After that 10mL HCl were added. The digestion was transferred to furnace and slowly raised temperature to 500° C and hold at this temperature for 1 hour. The crucible was removed, cooled and added 50mL deionized water and transferred to volumetric flask.

Transfer Factor

Transfer factor (TF) in fish tissues from the aquatic ecosystem, which include water and sediments, was calculated according to Kalfakakour and Akrida-Demertzi (2000) and Rashed (2001) as follows:

$$\text{TF} = \frac{\text{concentration of metal in fish tissue}}{\text{concentration of metal in environ (water or sediment)}}$$

TF greater than 1 indicates bioaccumulation of metals in fish tissue.

Chemical Analysis

The concentration of elements (Iron, Zinc, Arsenic, lead and cadmium) in different tissues (meat, gill and liver) of studied fish species and aquatic environs of the study area were analyzed tri-replicates by Flame Atomic Absorption Spectrometer (FAAS) (Perkin Elmer AAanalyst 800 and Winlab-32 software) in Universities' Research Centre (URC) at University of Yangon. The results were compared with WHO/FAO maximum permissible limits.

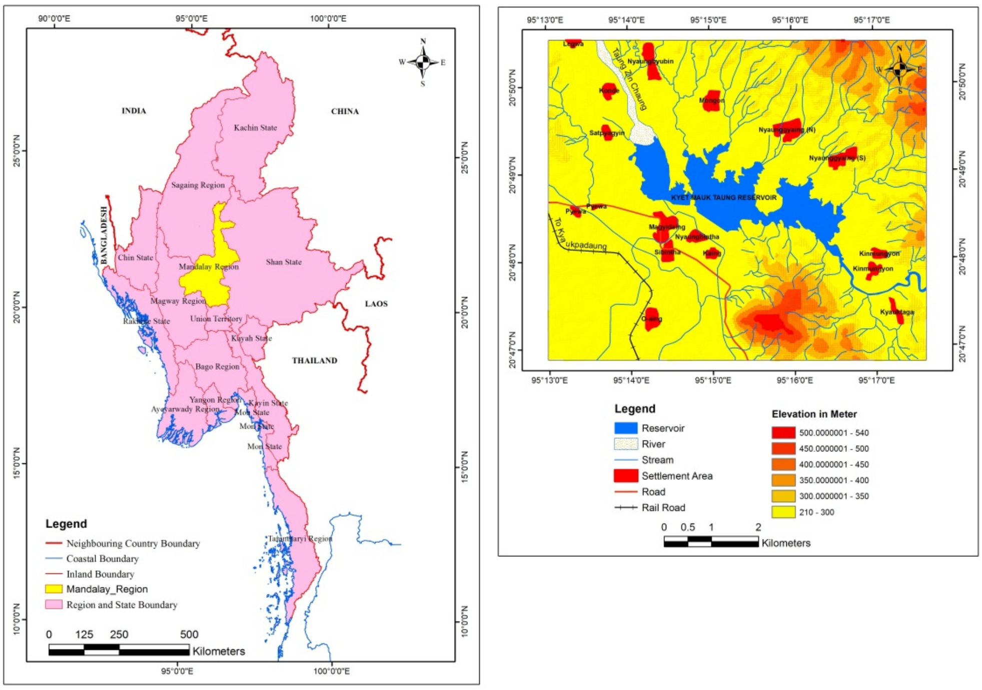

Figure 1 Map of the study area and study sites

Results

A total of 25 individuals of Tilapia fish (*Oreochromis* sp.) were collected from Kyet Mauk Taung Dam, Mandalay Region during the study period (Fig. 1). The size and total weight of collected fish species were presented in Table 1.

The concentrations of heavy metals (iron, zinc, arsenic, lead and cadmium) in different tissues (meat, gill and liver) of studied fish species were presented in Fig. 2, 3, 4, 5, and 6 respectively. Mean concentrations of heavy metals in different tissues of studied fish species were shown in Fig. 7.

The concentrations of iron in liver of studied fish species were found to be higher than those of other organs (meat and gill) during the study period except in September. In September, gill accumulated the highest iron concentrations.

The result showed that, gill accumulated the highest concentrations of zinc in November while lowest concentration in March. Iron and zinc concentrations in different tissues of studied fish species were found to be lower than those of maximum permissible limits recognized by WHO/ FAO (1989, 1990, 2008) (Table 2).

Arsenic concentrations were only found in gill in March and were found to be higher than those of maximum permissible limits.

In the results of present study, gill accumulated the highest concentrations of lead in September whereas muscle accumulated lowest concentrations in November. In July and September, lead concentrations of gill were found to be higher than those of maximum permissible limits recognized by WHO/ FAO.

In cadmium concentrations, liver accumulated the highest concentrations in November and the mean concentrations of Cd in liver were found within the maximum permissible limits recognized by WHO/ FAO.

The mean values of heavy metals (Fe, Zn, As, Pb and Cd) concentrations in different tissues of studied fish species were shown in Fig. (7). The highest concentrations of Fe and Cd were found in liver and those of Zn, As and Pb in gill. The lowest concentrations of all metals were found in meat. The mean values of metal concentrations in different tissues were found to be lower than the maximum permissible limits recognized by WHO/ FAO.

Iron and Zinc concentrations of water were found to be lower than those of maximum permissible limits recognized by WHO/ FAO. Cadmium (0.1 mg/L, 0.089 mg/L, and 0.083 mg/L) concentrations of water in November, January and March were higher than the MPL. Arsenic and lead concentrations of water during the study period were higher than the MPL.

Arsenic, lead and cadmium concentrations of sediment during the study period were observed to be lower than the "threshold effect concentration"(TEC)," midpoint effect concentration"(MEC), and "probable effect concentration" (PEC) (MacDonald *et al.*, 2000) except the arsenic concentration in January. In January, As concentrations of sediment (24.35 mg/L) were higher than MEC permissible limit (21.4 mg/L).

In addition, transferred factor of heavy metals in different organs (meat, liver and gill) of studied fish species from water and sediment were also determined (Table 3). It was found that the transfer factor of Fe in different organs (meat, gill and liver) from water were observed to be greater than that of the limitation value of 1. The transfer factors of Zn, Pb and Cd in different organs from water and sediment were found beyond the limited, which meant that above mentioned fish organs accumulated metal from water and sediment.

Table 1 Various sizes and weights of studied fish species (Mean ± Sd)

Sr. No.	Month	Number	Mean Total Length (Cm)			Mean Body Weight (G)		
1.	July	5	18.8	±	4.75	143.7	±	152.51
2.	September	5	20.7	±	5.25	167.72	±	105.9
3.	November	5	25.1	±	5.92	277.9	±	128.39
4.	January	5	20.4	±	4.04	139.1	±	96.68
5.	March	5	20.9	±	5.27	167.6	±	108.76
6.	May	5	25.1	±	5.24	226.5	±	131.9

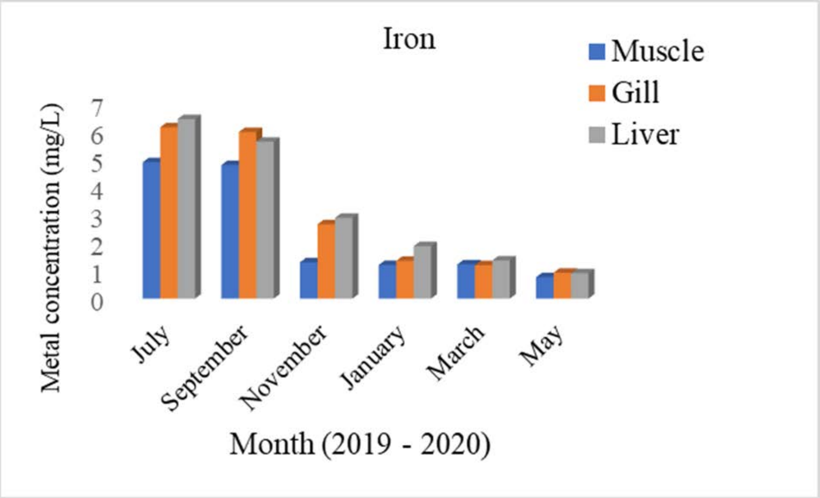

Figure 2 Iron concentrations in meat, gill and liver of studied fish species

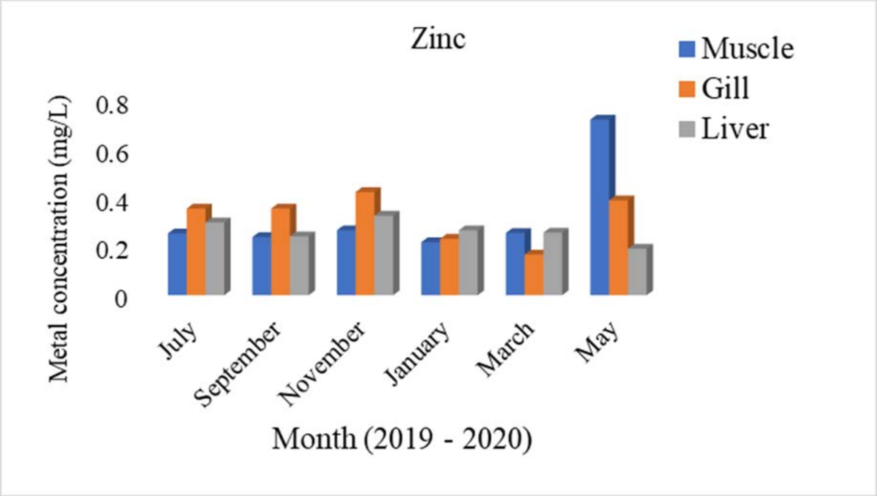

Figure 3 Zinc concentrations in meat, gill and liver of studied fish species

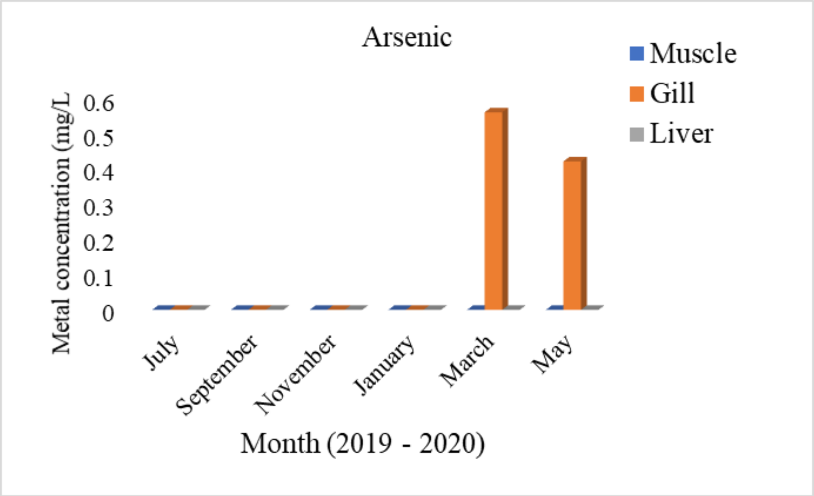

Figure 4 Arsenic concentrations in meat, gill and liver of studied fish species

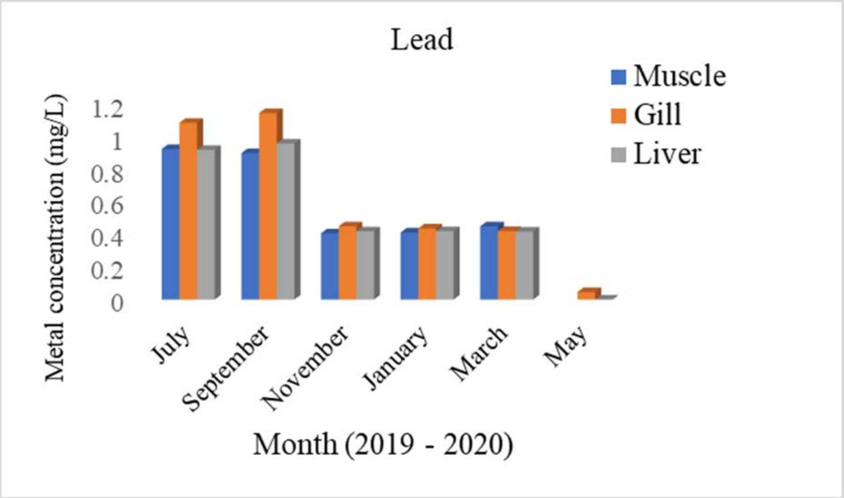

Figure 5 Lead concentrations in meat, gill and liver of studied fish species

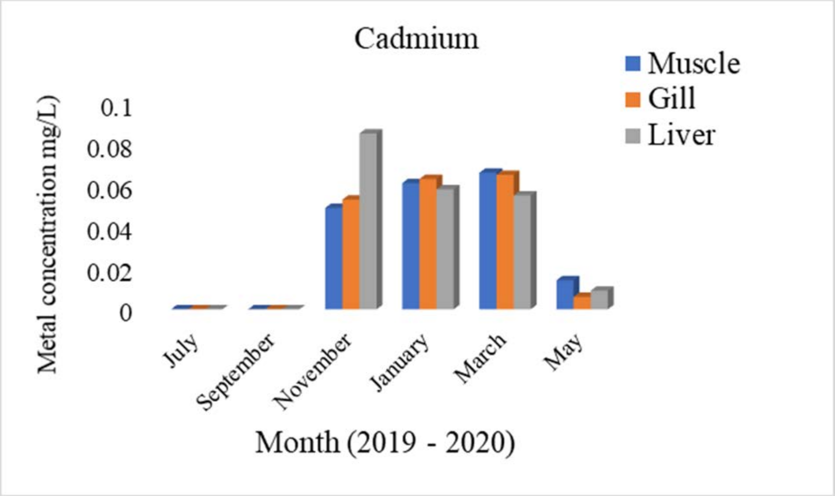

Figure 6 Cadmium concentrations in meat, gill and liver of studied fish species

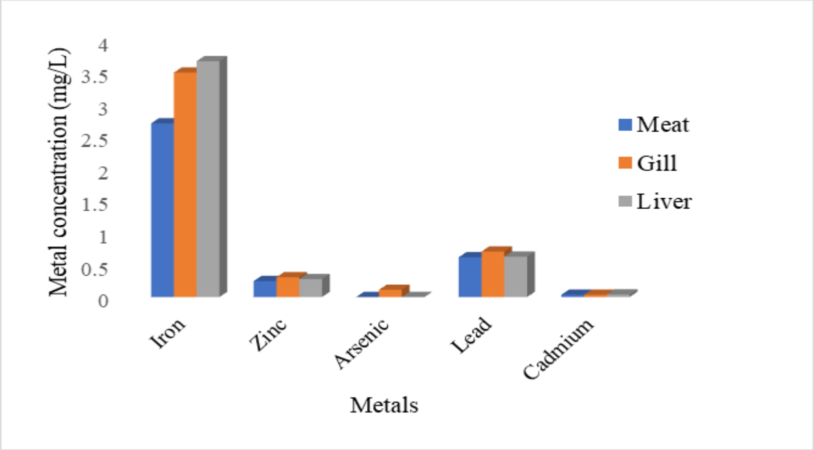

Figure 7 Mean values of metal concentrations in meat, gill and liver of studied fish species

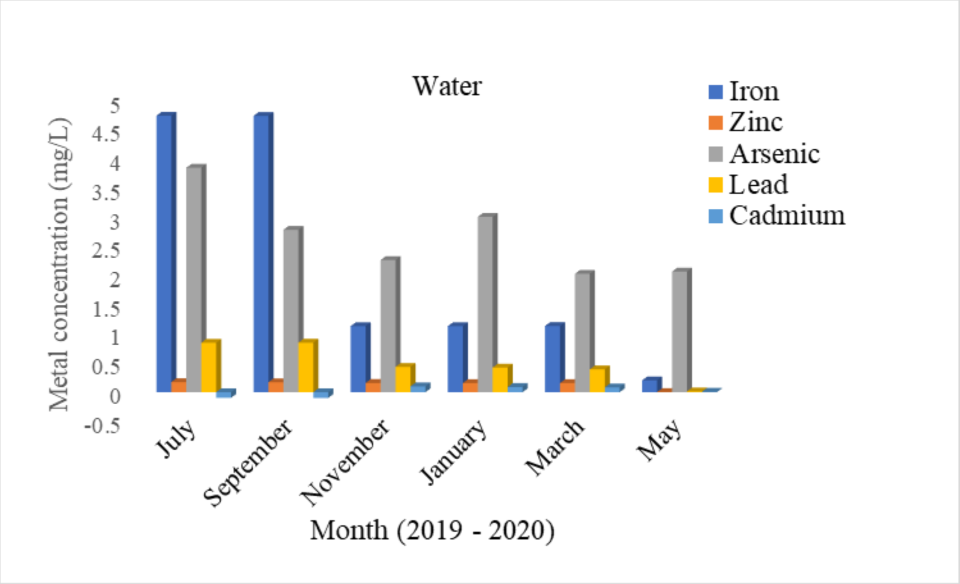

Figure 8 Metal concentrations in water during studied period

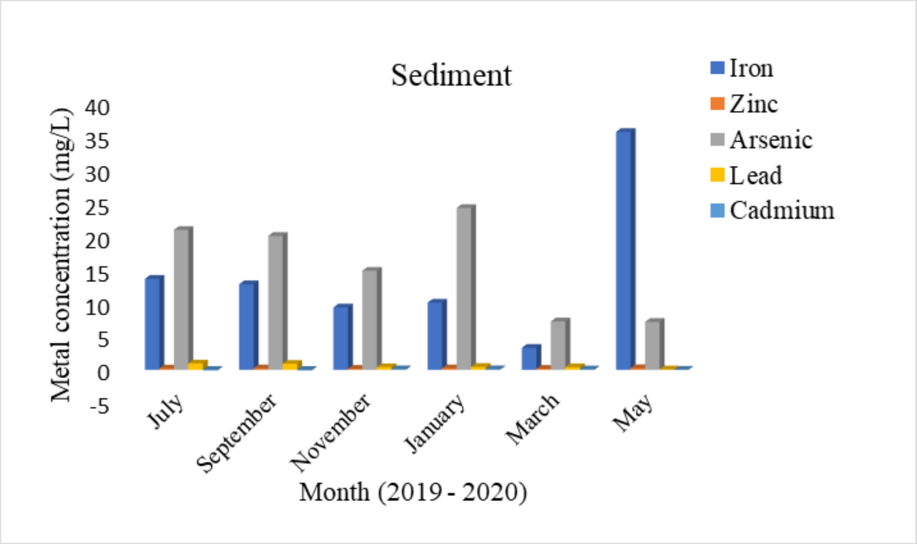

Figure 9 Metal concentrations in sediment during studied period

Table 2 Maximum permissible limits of metal concentrations (mg/L) stated in WHO and FAO guidelines

Sr. No.	Metal	WHO/FAO limit	WHO limit	Sediment		
		Muscle	Water	TEC	MEC	PEC
1.	Fe	100	5	20000	30000	40000
2.	Zn	40	3	120	290	460
3.	As	0.26	0.01	9.8	21.4	33
4.	Pb	1	0.05	36	83	130
5.	Cd	0.2	0.01	0.99	3	5

TEC = Threshold effect concentration
MEC = Midpoint effect concentration
PEC = Portable effect concentration

Table 3 The TF of heavy metals from water and sediment in meat, gill and liver of studied fish species

Metal	TF from water			TF from sediment		
	Meat	Gill	Liver	Meat	Gill	Liver
Iron	1.1	1.4	1.47	0.173	0.22	0.22
Zinc	2.397	2.35	1.94	1.531	1.5	1.24
Arsenic	0	0.061	0	0	0.01	0
Lead	1.08	1.21	1.1	1	1.11	1
Cadmium	2.27	2.21	2.5	2.9	3	3.5

Discussion

Fish are an important food source and represent a major part of many natural food chains. Therefore, the levels of contaminants in fish are of particular interest because of the potential effects of these polluting substances on the fish themselves and on the organisms that consume them, including humans (Burger and Gochfeld 2005). This study was undertaken to investigate the concentrations of Fe, Zn, As, Pb and Cd in different tissues (muscle, gill and liver) of Tilapia fish species and their environs (water and sediment) collected from the Kyet Mauk Taung Dam, Mandalay Region. Moreover, the values of transfer factor in different tissues from aquatic environs (water and sediment) were evaluated. The levels of heavy metal were determined in this species because of its importance for human consumption.

This investigation showed that Fe and Cd concentrations (mean total) were highest in the liver and lowest in the muscle. Zhao, *et al.,* (2012) stated that the accumulation of Fe in the liver is likely linked to its role in metabolism. Fe tends to accumulate in hepatic tissues due to physiological role of the liver in the blood cells and hemoglobin synthesis (Gorur, *et al*., 2012). On the other hand, the liver also showed high level toxic metals such as Cd to displace the normally metallothionein (MT) associated essential metals in hepatic tissues (Amiard, *et al.*, 2006). Similar results of high Fe and Cd in the liver were observed in many field studies according to (Cho Cho Thin, 2017, Zhao, *et al.*, 2012, Amundsen, *et al*., 1997, Dural, *et al*., 2007).

In the present study, the concentrations of Zn, As, and Pb were found to be highest in the gill and lowest in the muscles. Many volcanic complexes are all characterized by geogenic enrichment of Zn (Petrik, *et al*., 2018). The high concentrations of Zn, As and Pb may be from volcanic soil and volcanic ash and anthropogenic sources in the study area.

Gills are the main route of metal iron exchange from water (Qadir and Malik, 2011). They have large surface areas that facilitate rapid diffusion of toxic metals (Dhaneesh, 2012). Therefore, it is suggested that metals accumulated in gills are mainly concentrated from water. This is an agreement with the finding of Cho Cho Thin (2017). Similar result for high Zn, As and Pb concentrations in gills were recorded by Avenant-Oldewage and Marx (2000) and Abu-Hilal, and Ismail, 2008.

In the present study, the studied fish species always showed the lowest concentrations of tested metals (Fe, Zn, As, Pb and Cd) in the muscles. Fe and Cd were accumulated mainly in the liver while Zn, As and Pb revealed their highest concentrations in the gills. Thus, the differences noticed in the levels of accumulation in different organs studied fish species can be attributed to the differences in their physiological roles toward maintaining homeostasis, feeding habits, regulatory ability and behaviors of the species (Cross, *et al*., 1973). However, the majorly of the muscle (meat) had the least concentrations of heavy metals compared with other muscles (gill and liver) in the studied fish species. This is in agreement with the previous finding by Cho

Cho Thin (2017) and Ishaq *et al*., (2011) which showed that meat is not an active organ in the accumulation of heavy metals. Gills, on the other hand, has been reported as metabolically active site and can accumulate heavy metals in higher level. This is evidenced by the position that the gills occupied in the accumulation pattern for the heavy metals (Olaifa *et al*., 2004). The mean values of metal concentrations in different tissues were found to be lower than the maximum permissible limits recognized by WHO/ FAO.

The concentrations of Fe and Zn of water were found to be lower than those of maximum permissible limits recognized by WHO/ FAO. As, Pb and Cd concentrations of water during the study period were higher than the MPL. The high levels of As, Pb and Cd in water can be related (attributed) to industrial and agricultural discharge (Mason, 2002). In the present study, the high levels of heavy metal came from agricultural activities because more than 2515 hectares of agricultural lands are located near the Dam.

The obtained results of all metal concentrations (Fe, Zn, As, Pb and Cd) from sediment during the study period were observed to be lower than the "threshold effect concentration"(TEC)," midpoint effect concentration"(MEC), and "probable effect concentration" (PEC) (MacDonald *et al.,* 2000).

The results showed that the transfer factors of all elements in different tissues of studied fish species from water and sediment were greater than 1 except for Fe from sediment and As from water and sediment. This means that the fish undergo bioaccumulation of these tested metals from the aquatic environs (water and/or sediment) (Kalfakakour and Akrida-Demertzi, 2000; Rashed, 2001). This study indicates that, this species is safe for human consumption. However, it was found that there was high bioaccumulation of heavy metals in fish tissues. Therefore, a regular monitoring of heavy metal levels in fishes is necessary.

Conclusion

In the present study, heavy metals concentrations in studied fish species were found to be lower than the maximum permissible limits. Based on the results, it is concluded that it seems to be appropriate for eating the studied fish species. According to the results of Transfer Factors, heavy metals accumulated in different tissues of the studied fish species came from water and sediment. Therefore, regular monitoring of heavy metal levels in fish tissues is necessary.

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